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RESEARCH PAPER

Integrated weed management in soybean [*Glycine max* (L.) Merrill]

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Abstract: A field experiment was conducted to study the effect of integrated weed management on growth and yield of soybean at Agricultural Research Station, Hukkeri, Belagavi, during *kharif*, 2022. The experiment was laid out in RCBD with three replications. The experiment consisted of 10 treatments comprising of 8 pre-emergence herbicides (Sulfentrazone + Clomazone, Sulfentrazone + Metolachlor, Metolachlor, Metribuzin, Pendimethalin + Imazethapyr, Flumioxazin, Pendimethalin, Diclosulam) and they were tested along with one intercultivation operation. Among the herbicidal treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly lower weed density (2.27 m^{-2}), dry weight of weeds (2.42 g m^{-2}) and higher weed control efficiency (88%) for total weeds at 15 days after herbicide application (DAHA) with lower weed index (5.30%). It also recorded higher plant height (53.89 cm), number of branches (7.75 $plant^{-1}$), total dry matter production (16.80 g $plant^{-1}$), seed yield (2413 kg ha^{-1}), gross returns (₹ 115824 ha^{-1}), net returns (₹ 70887 ha^{-1}) and benefit cost ratio (2.58). The lower seed yield, net returns and benefit cost ratio was recorded with Metribuzin 70% WP (0.35 kg *a.i.* ha^{-1}) @ 500 g ha^{-1} as PE followed by one inter cultivation at 35 DAS due to phytotoxicity of Metribuzin on soybean. Seed quality was not influenced by herbicidal treatments.

Key words: Economics, Herbicides, Pre emergence, Ready mix, Soybean, Weeds

Introduction

Soybean [*Glycine max* (L.) Merrill] is an important rainy season legume and an oil seed crop. It belongs to the family Leguminoseae, sub family Papillionaceae and genus Glycine. Soybean evolved from *Glycine ussuriensis*, a wild legume native to Northern China and used in China since 11th century B.C. It is economically one of the most important legume crops in the world. It has high yield potential (30-35 q ha^{-1}) and being a legume crop, it increases the soil fertility by fixing atmospheric-nitrogen in soil. It is considered as golden bean, miracle bean or wonder crop of the 20th century because of its important characters like the grain contains 20 per cent edible oil, 40 per cent high quality protein, minerals (Ca, Mg, P and Fe), vitamins (C and A) and amino acids with high nutritive value. Cultivation of Soybean improves soil fertility through atmospheric nitrogen fixation and addition of leaf residues.

Soybean is one of India's major pulse and oil seed crop. During the year 2021-22, soybean was sown on 12.15 million hectares and with a production of 12.99 million tonnes and productivity of 1069 kg ha^{-1}. Among the states, Madhya Pradesh stood first with 5.51 million ha followed by Maharashtra (4.59 million ha), Rajasthan (1.15 million ha) with respect of area. In Karnataka, it occupies an area of 3.81 Lakh ha with a production of 4.37 MT and productivity of 1147 kg ha^{-1} which is too low when compared to world productivity (Anon., 2022). In Karnataka, Belagavi, Dharwad, Haveri, Bagalkot, Shivamoga and Bidar are the important districts from the point of view of its production.

Soybean being a rainy season crop, it suffers heavily due to the competitive stress of the grasses, broad leaf weeds and sedges. Billore *et al.* (1999) reported that the existence of weeds depending upon their types, intensity and duration of competition with crop, weed causes about 35-70% reduction in seed yield of soybean due to its slow initial growth, available soil moisture and congenial temperature. Thus, one of the most important aspects of soybean production is weed management. Uncontrolled weeds not only reduce soybean yield through their competition for light, nutrients, and moisture but also reduce harvest efficiency severely. Control of the weeds in early stages (up to 30 DAS) of soybean is very critical and if not done properly, yield losses may reach up to 43% (Bhan *et al.* 1974). Weed flush comes at the same time in almost all the *kharif* crops, which also restricts the availability of manpower for weeding operation in this crop. The problems become more critical when farmers do not get their field weeded at right time either due to the man power shortage or due to heavy rains which results into lower productivity of soybean.

For the control of weeds in soybean, spraying of pre-emergent herbicides helps to minimize the crop weed competition during such critical growth stage resulting in higher crop yields. In soybean there are few pre-emergence herbicides which are well adopted by farmers like alachlor and pendimethalin. Herbicides in isolation, however are unable to provide complete weed control because of their selective kill and also these herbicides are going to be banned shortly in market. Hence, new generation herbicides alone or in combi with different mode of actions and their use can be made more effective if supplemented with hand weeding or hoeing. A judicious combination of chemical and cultural methods of weed

control would not only reduce the expenditure on herbicides but would benefit the crop timely by providing proper aeration and conservation of moisture (Prakash *et al*. 1991). In cases where application of post-emergence herbicides is not possible due to frequent rains, work load of farmer or unavailability of labour and additional labour cost the, farmers are facing problems in controlling weeds in soybean. It was therefore felt that a judicious combination of chemical and mechanical methods of weed control is necessary for effective control of weeds in soybean.

Material and methods

A field experiment was conducted during *kharif*, 2022 at Agricultural Research Station, Hukkeri in Belagavi district of Karnataka on vertisol having pH 8.22 and EC 0.31 dS m^{-1}. The soil was high in organic carbon content (0.56%) and available P_2O_5 (34.58 kg ha^{-1}), and medium in available N (234.78 kg ha^{-1}) with high available K_2O content (440.51 kg ha^{-1}). The experimental site was located at a latitude of 16^0 13' 48.00" North, longitude of 74^0 35' 59.99" East and at an altitude of 631 m above mean sea level in Northern Transition Zone of Karnataka (Zone 8). During the year 2022, a total rainfall of 1025.2 mm was received in 65 rainy days from January 2022 to December 2022 as against the normal rainfall of 741.6 mm. The highest rainfall of 222.4 mm was received in the month of September followed by followed by October (217.3 mm).

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of 10 treatments involving 8 pre-emergence herbicides (Sulfentrazone + Clomazone, Sulfentrazone + Metolachlor, Metolachlor, Metribuzin, Pendimethalin + Imazethapyr, Flumioxazin, Pendimethalin, Diclosulam) and they were tested with one intercultivation operation. The land was ploughed once after the harvest of the previous crop, followed by two harrowing. At the time of sowing, the land was prepared to a fine seedbed and the plots were laid out. The variety DSb-34 was used and fertilizer application was followed on the basis of the plant population occupied by crop. The full amount of fertilizer in the form of urea, di ammonium phosphate and Murate of potash as per recommended package of practice 40:80:25 kg N, P_2O_5 and K_2O per ha was applied. The crop was sown on 8th June, 2022 with a spacing of 45 × 10 cm. The crop grown with the residual moisture of monsoon rains without any protective irrigations. Harvesting was done at physiological maturity of the crop. The net plot area as per the treatments was harvested by cutting the plants to the ground level. After harvesting, the plants were bundled and allowed for sun drying. After complete sun drying, the crop was threshed by beating with wooden sticks. The separated seeds were winnowed, cleaned and grain and haulm yield were expressed in kilogram per hectare. The harvest index was calculated by using the formula suggested by Donald, 1962.

The weed components and yield parameters of soybean were recorded from the net plots and seed yield was converted to hectare basis in kilograms. The economics of each treatment was computed with prevailing market prices of that year. The yield was further computed for gross and net returns as well BC ratio to assess the productivity. The benefit- cost ratio was worked out by dividing the gross returns by the total cost of cultivation of respective treatments. The data collected from the experiment at different growth stages and at harvest were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used for 'F' and 't' tests was P=0.05. Critical Difference (CD) values were calculated at 5 per cent probability level if the F test will found to be significant.

Results and discussion

Weed flora in experimental area

The dominant weed species observed in experimental field were *Brachiaria reptans, Cynodon dactylon*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis, Dinebra retroflexa* and *Echinochloa colona* among grasses, *Abutilon indicum, Acalypha indica, Alternanthera sessilis*, *Amaranthus spinosus*, *Argemone mexicana*, *Brachiaria reptans*, *Chenopodium album, Commelina benghalensis, Convolvulus arvensis*, *Euphorbia geniculata*, *Parthenium hysterophorus*, *Phyllanthus niruri*, *Portulaca oleraceae, Tribulus terrestris* and *Trichodesma indicum* among broad leaved weeds and *Cyperus rotundus* among sedges.

Weed dry weight and weed control efficiency of soybean as influenced by different weed management treatments (Table 1.)

Weed dry weight (g m^{-2})

At 15 DAHA, the dry weight of total weeds differed significantly due to various weed management treatments. Among the different treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly lower weed dry weight (2.42 g m^{-2}) and it was on par with application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (2.75 g m^{-2}). At 30 DAHA, among the different weed management treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly lower dry weight of total weeds (4.41 g m^{-2}). At 45 DAHA, among the different weed management treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly lower weed dry weight (4.14 g m^{-2}) and was on par with application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (4.75 g m^{-2}). At 60 DAHA, the dry weight of total weeds differed significantly due to various weed management treatments. Among the different weed management treatments, significantly lower dry weight of total weeds (5.46 g m^{-2}) was recorded with the application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS and the next best treatment was application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (6.02 g m^{-2}). The lower weed dry weight in these treatments

Table 1. Dry weight of total weeds and weed control efficiency of soybean at different growth stages as influenced by weed management treatments

Treatment	Dry weight of total weeds (g m^{-2})				Weed control efficiency (%)			
	15 DAHA	30 DAHA	45 DAHA	60 DAHA	15 DAHA	30 DAHA	45 DAHA	60 DAHA
T_1: Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) Ready mix (RM) @ 1250 g ha^{-1} as Pre emergence (PE) followed by one inter cultivation at 35 days after sowing (DAS)	2.42* (5.38)	4.41* (18.92)	4.14* (16.63)	5.46* (29.30)	88	80	87	81
T_2: Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	2.75 (7.04)	4.79 (22.48)	4.75 (22.02)	6.02 (35.73)	84	76	83	76
T_3: Metolachlor 50% EC (1000 ml *a.i.* ha^{-1}) @ 2000 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	3.52 (11.89)	5.53 (30.07)	5.58 (30.67)	6.91 (47.25)	73	68	76	69
T_4: Metribuzin 70% WP (0.35 kg *a.i.* ha^{-1}) @ 500 g ha^{-1} as PE followed by one inter cultivation at 35 DAS	3.83 (14.15)	6.52 (41.99)	6.17 (37.62)	7.69 (58.62)	68	55	71	61
T_5: Pendimethalin 30% EC + Imazethapyr 2% EC (900 + 600 g *a.i.* ha^{-1}) RM @ 3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS	3.09 (9.04)	5.13 (25.85)	5.09 (25.37)	6.49 (41.62)	79	72	80	73
T_6: Flumioxazin 50% SC (125 g *a.i* ha^{-1}) @ 250 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	3.37 (10.88)	5.37 (28.29)	5.36 (28.24)	6.70 (44.34)	75	69	78	71
T_7: Pendimethalin 30% EC (1 kg *a.i.* ha^{-1}) @ 3.3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	3.79 (13.87)	6.31 (39.44)	5.98 (35.30)	7.48 (55.41)	68	57	73	64
T_8: Diclosulam 84% WDG (26 g *a.i.* ha^{-1}) @ 31 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	3.26 (10.13)	5.25 (27.07)	5.20 (26.61)	6.57 (42.73)	77	71	79	72
T_9: Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.41 (5.30)	100	100	100	97
T_{10}: Weedy check	6.65 (43.69)	9.65 (92.63)	11.40 (129.59)	12.35 (152.02)	–	–	–	–
S. Em. ±	0.13	0.19	0.19	0.25	2.35	2.18	2.36	2.21
C. D. (P = 0.05)	0.38	0.58	0.57	0.74	7.06	6.14	7.08	6.63

WP- Wettable powder, RM- Ready mix, PE- Pre emergence, DAS- Days after sowing, EC-Emulsifiable concentrate, SC- Suspension concentrates, RPP- Recommended package of practice, WDG- Water dispersible granules, DAHA- Days after herbicide application

* Square root (Öx+0.5) transformed values and the figures in parenthesis indicate the original values

might be due to better efficacy and prolonged effectiveness of herbicides which reduced weed growth and even caused the rapid depletion of carbohydrate reserves of weeds already germinated through rapid desiccation, bleaching of leaves, stunting and necrosis of tissues, reduction in leaf area and diminution of photosynthesis process. These findings are in line with Vyas and Kushwah (2008), Singh *et al.* (2017) and Meena (2019).

Weed control efficiency (%)

At 15 DAHA, total weed control efficiency differed significantly due to various weed management treatments. Among the treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher total weed control efficiency (88%) than other treatments which is depicted in Fig. 1. At 30 DAHA, Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS application recorded significantly higher total weed control efficiency (80%) compared to rest of the herbicide applied treatments. At 45 DAHA, among the treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher total weed control efficiency (87%) than other treatments. At 60 DAHA, significantly higher total weed control efficiency (81%) was recorded with application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS and the next best treatment was Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (76%). This may be due to decreased weed density and dry matter as a result of the administration of

Table 2. Herbicide efficiency index and Weed management index in soybean at different growth stages as influenced by weed management treatments

Treatment	Herbicide efficiency index				Weed management index			
	15 DAHA	30 DAHA	45 DAHA	60 DAHA	15 DAHA	30 DAHA	45 DAHA	60 DAHA
T_1: Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) Ready mix (RM) @ 1250 g ha^{-1} as Pre emergence (PE) followed by one inter cultivation at 35 days after sowing (DAS)	10.82	6.59	10.49	6.98	1.54	1.69	1.54	1.67
T_2: Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	7.81	5.24	7.50	5.42	1.52	1.67	1.53	1.66
T_3: Metolachlor 50% EC (1000 ml *a.i.* ha^{-1}) @ 2000 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	1.97	1.67	2.30	1.75	0.75	0.81	0.71	0.79
T_4: Metribuzin 70% WP (0.35 kg *a.i.* ha^{-1}) @ 500 g ha^{-1} as PE followed by one inter cultivation at 35 DAS	0.48	0.34	0.54	0.40	0.23	0.29	0.22	0.26
T_5: Pendimethalin 30% EC + Imazethapyr 2% EC (900 + 600 g *a.i.* ha^{-1}) RM @ 3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS	4.78	3.58	5.11	3.65	1.27	1.40	1.25	1.39
T_6: Flumioxazin 50% SC (125 g *a.i* ha^{-1}) @ 250 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	2.18	1.80	2.52	1.88	0.74	0.79	0.70	0.78
T_7: Pendimethalin 30% EC (1 kg *a.i.* ha^{-1}) @ 3.3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	0.59	0.44	0.70	0.52	0.29	0.35	0.27	0.31
T_8: Diclosulam 84% WDG (26 g *a.i.* ha^{-1}) @ 31 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	4.11	3.29	4.69	3.43	1.27	1.37	1.22	1.35
T_9: Weed free check	_	_	_	_	_	_	_	_
T_{10}: Weedy check	_	_	_	_	_	_	_	_
S. Em. ±	0.14	0.10	0.14	0.10	0.03	0.04	0.04	0.04
C. D. (P = 0.05)	0.42	0.29	0.43	0.30	0.10	0.11	0.12	0.13

WP - Wettable powder, RM - Ready mix, PE - Pre emergence, DAS - Days after sowing, EC - Emulsifiable concentrate, SC - Suspension concentrates, RPP - Recommended package of practice, WDG - Water dispersible granules, DAHA- Days after herbicide application

combination herbicides and inter cultivation at the appropriate growth stage. The obtained results closely match the conclusions of Pandya *et al.* (2005), Vyas and Kushwah (2008) and Rawat *et al.* (2017).

Herbicide efficiency index and Weed management index of soybean as influenced by different weed management treatments (Table 2.)

Herbicide efficiency index

At 15 DAHA, the herbicide efficiency index differed significantly due to different weed management treatments. Significantly higher herbicide efficiency index (10.82) was observed in application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE *fb* one inter cultivation at 35 DAS and it was followed by application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (7.81). At 30 DAHA, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher herbicide efficiency index (6.59) compared to rest of the herbicide applied treatments. At 45 DAHA, among the treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher herbicide efficiency index (10.49) than other treatments At 60 DAHA, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher herbicide efficiency index (6.98) compared to rest of the herbicide applied treatments and it was followed by application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (5.42).

Weed management index

At 15 DAHA, among the treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher weed management index

(1.54) and it was found to be on par with Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (1.52). At 30 DAHA, among the different weed management treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher weed management index (1.69). At 45 DAHA, among the herbicide applied treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher weed management index (1.54). At 60 DAHA, significantly higher weed management index (1.67) was recorded in application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 and it was found to be on par with application of DAS Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (1.66).

Yield attributes, seed yield and weed index as influenced by different weed management treatments (Table 3.)

Among the herbicidal treatments, application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1} RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS recorded significantly higher number of pods per plant (42.00) and it was followed by application of Sulfentrazone 120 + Metolachlor 375% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (41.33).

Among the treatments, weed free check recorded significantly higher (15.47 g) seed yield per plant and it was on par with application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (14.73 g) and Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (14.28 g). This may be the result of more branches with more flowers on each plant and also because of lesser weed population when the crop is mature, which allows plant to use its resources more effectively which led to increased pod production on each plant and better pod filling. These results are corroborating according to the findings of Patel *et al.* (2015) and Meena (2019).

The data resulted that, there was no significant difference among the treatments at harvest with respect showed to seed index of soybean. Among the herbicidal treatments, numerically higher seed index (14.58 g) was recorded with the application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS.

Table 3. Yield attributes, seed yield and weed index as influenced by different weed management treatments

Treatment	Number of pods per plant	Seed yield per plant (g)	Seed index (g)	Seed yield (kg ha^{-1})	Weed index (%)
T_1: Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) Ready mix (RM) @ 1250 g ha^{-1} as Pre emergence (PE) followed by one inter cultivation at 35 days after sowing (DAS)	42.00	14.73	14.58	2413	5.30
T_2: Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	41.33	14.28	14.43	2343	8.19
T_3: Metolachlor 50% EC (1000 ml *a.i.* ha^{-1}) @ 2000 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	36.00	12.04	13.77	1586	37.79
T_4: Metribuzin 70% WP (0.35 kg *a.i.* ha^{-1}) @ 500 g ha^{-1} as PE followed by one inter cultivation at 35 DAS	31.33	8.76	12.41	1189	52.91
T_5: Pendimethalin 30% EC + Imazethapyr 2% EC (900 + 600 g *a.i.* ha^{-1}) RM @ 3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS	39.00	13.12	14.23	2062	19.04
T_6: Flumioxazin 50% SC (125 g *a.i* ha^{-1}) @ 250 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	36.33	12.23	13.86	1596	37.43
T_7: Pendimethalin 30% EC (1 kg *a.i.* ha^{-1}) @ 3.3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	33.00	10.35	12.90	1227	51.52
T_8: Diclosulam 84% WDG (26 g *a.i.* ha^{-1}) @ 31 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	38.33	13.03	14.19	2023	20.59
T_9: Weed free check	44.33	15.47	14.77	2549	0.00
T_{10}: Weedy check	28.00	7.06	12.10	1031	60.97
S. Em. ±	1.64	0.47	0.60	69.74	1.37
C. D. (P = 0.05)	4.88	1.39	NS	207.23	4.02

WP- Wettable powder, RM- Ready mix, PE- Pre emergence, DAS- Days after sowing, EC-Emulsifiable concentrate, SC- Suspension concentrates, RPP- Recommended package of practice, WDG- Water dispersible granules, NS- Non significant

Weed free check recorded significantly higher seed yield (2549 kg ha^{-1}) and was on par with treatments receiving application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (2413 kg ha^{-1}) and application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (2343 kg ha^{-1}). The higher seed yield due to better weed management led to significantly high growth parameters *viz*., plant height, number of branches, leaf area, number of nodules, total dry matter production and yield parameters *viz*., number of pods per plant, seed yield per plant and seed index. These treatments effectively reduced the weed growth, which was reflected in less weed competition with crops for resources including nutrients, moisture, space, and light. The results were with the similar findings of Bhumika *et al.* (2015), Gupta and Patel (2015), Singh *et al.* (2018), Meena (2019) and Koturwar *et al.* (2022).

Among the herbicidal treatments, significantly lower weed index (5.30%) was recorded with application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE followed by one inter cultivation at 35 DAS and it was followed by application of Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (8.19 %) which is depicted in Fig. 1.

Effect of different weed management treatments on economics of soybean (Table 4)

Among the treatments, higher cost of cultivation was recorded in weed free plot (`45487 ha$^{-1}$) and which was followed by application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha$^{-1}$) RM @ 1250 g ha$^{-1}$ as PE followed by one inter cultivation at 35 DAS (`44937 ha^{-1}).

Among all the treatments, significantly higher gross returns were observed with weed free check (`122352 ha$^{-1}$), however, it was found to be on par with treatments, Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha$^{-1}$) RM @ 1250 g ha$^{-1}$ as PE followed by one inter cultivation at 35 DAS (`115824 ha^{-1}) and Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS (`112464 ha^{-1}). The higher gross returns of these treatments were attributed to higher seed yield which was due to higher weed control efficiency and lower weed index.

Among the treatments, significantly higher net returns was noticed with weed free check (`76865 ha$^{-1}$) and it was on par with application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha$^{-1}$) RM @ 1250 g ha$^{-1}$ as PE followed by one inter cultivation at 35 DAS (`70887 ha^{-1}) and Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1}as PE followed by one inter cultivation at 35 DAS (` 68027 ha^{-1}). This was because of higher gross returns which are in turn governed by higher economic yield and fetching

Table 4. Economics of soybean cultivation as influenced by different weed management treatments

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BC ratio
T_1: Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) Ready mix (RM) @ 1250 g ha^{-1} as Pre emergence (PE) followed by one inter cultivation at 35 days after sowing (DAS)	44937	115824	70887	2.58
T_2: Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) RM @ 2500 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	44437	112464	68027	2.53
T_3: Metolachlor 50% EC (1000 ml *a.i.* ha^{-1}) @ 2000 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	41547	76128	34581	1.83
T_4: Metribuzin 70% WP (0.35 kg *a.i.* ha^{-1}) @ 500 g ha^{-1} as PE followed by one inter cultivation at 35 DAS	40637	57072	16435	1.40
T_5: Pendimethalin 30% EC + Imazethapyr 2% EC (900 + 600 g *a.i.* ha^{-1}) RM @ 3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS	42607	98976	56369	2.32
T_6: Flumioxazin 50% SC (125 g *a.i* ha^{-1}) @ 250 ml ha^{-1} as PE followed by one inter cultivation at 35 DAS	42812	76608	33796	1.79
T_7: Pendimethalin 30% EC (1 kg *a.i.* ha^{-1}) @ 3.3 l ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	41767	58896	17129	1.41
T_8: Diclosulam 84% WDG (26 g *a.i.* ha^{-1}) @ 31 g ha^{-1} as PE followed by one inter cultivation at 35 DAS (RPP)	42299	97104	54805	2.30
T_9: Weed free check	45487	122352	76865	2.69
T_{10}: Weedy check	37587	49488	11901	1.32
S. Em. ±	_	3347	3347	0.07
C. D. (P = 0.05)	_	9948	9948	0.22

WP- Wettable powder, RM- Ready mix, PE- Pre emergence, DAS- Days after sowing, EC-Emulsifiable concentrate, SC- Suspension concentrates, RPP- Recommended package of practice, WDG- Water dispersible granules, NS- Non significant

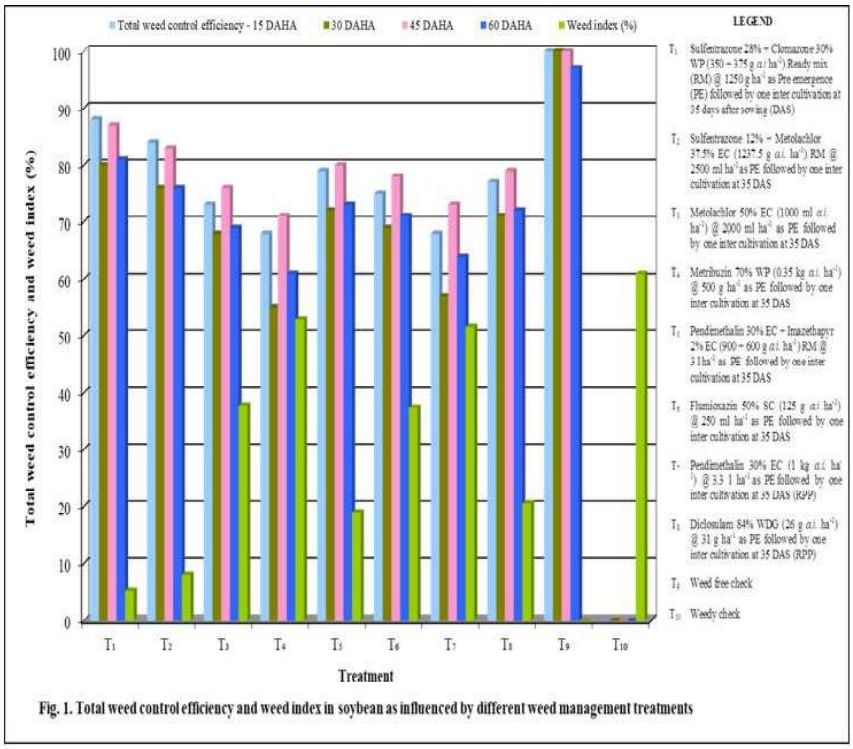

Fig. 1. Total weed control efficiency and weed index in soybean as influenced by different weed management treatments

better market price. The results obtained are in accordance with Patel *et al.* (2015) and Rawat *et al.* (2017).

Weed free check recorded significantly higher benefit cost ratio (2.69) compared to other treatments and it was on par with application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) RM @ 1250 g ha^{-1} as PE *fb* one inter cultivation at 35 DAS (2.58) and Sulfentrazone 12% + Metolachlor 37.5% EC (1237.5 g *a.i.* ha^{-1}) @ 2500 ml ha^{-1} as PE (RM) *fb* one inter cultivation at 35 DAS (2.53).

Conclusion

Application of Sulfentrazone 28% + Clomazone 30% WP (350 + 375 g *a.i* ha^{-1}) Ready Mix @ 1250 g ha^{-1} as pre emergence followed by one inter cultivation at 35 days after sowing resulted in significantly higher weed control efficiency (88-81%) at 15 - 60 days after herbicidal application, seed yield (2413 kg ha^{-1}), net returns (`70887 ha^{-1}) and benefit cost ratio (2.58).

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